USE OF COMPUTERS TO EXCLUDE THE INFLUENCE OF RADIOMETER INSTABILITY UPON MEASUREMENT RESULTS

By

S. L. Domnin, V. A. Yefanov, V. A. Korsenskiy, I. G. Moiseyev, N. S. Nesterov

(NASA-TM-75374) USE OF COMPUTERS TO EXCLUDE THE INFLUENCE OF RADIOMETER INSTABILITY UPON MEASUREMENT RESULTS (National Aeronautics and Space Administration) 12 p HC A02/MF A01 CSCL 14B G3/35

N79-12415

Unclas 38009

Translation of "Primeneniye EVM dlya isklyucheniya vliyaniya nestabil'nosti radiometrov na rezul'taty izmereniy," Izvestiya Krymskoy Astrofizicheskoy Observatorii, Vol. 57, 1977, pp. 199-204

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 NOVEMBER 1978

USE OF COMPUTERS TO EXCLUDE THE INFLUENCE OF RADIOMETER INSTABILITY UPON MEASUREMENT RESULTS

S.L. Domnin, V.A. Yefanov, V.A. Korsenskiy,
I.G. Moiseyev, N.S. Nesterov

As is known, the technical sensitivity of all types of radiometers greatly depends on their stability [1]. Different methods may be used to increase the stability of the radiometer amplification coefficient. To a certain extent, these methods may either decrease the variations in the receiving equipment amplification [2,3] or they may provide information about the condition of the receiving-amplification channel synchronously with the recording of the signal [4,5]. All of these methods have certain drawbacks - for example, the complexity of the system used [2,3] which lowers the sensitivity, and the necessity of the subsequent concurrent processing of registograms indicating the condition of the receiver amplification and the useful signal [4,5]. /199*

The Crimean Astrophysical Observatory of the USSR Academy of Sciences has proposed a method for recording radioastronomical information making it possible to produce a radiometer which is practically insensitive to great fluctuations in the equipment amplification coefficient.

The method essentially consists of dividing the useful signal 1 by a certain reference signal (T_0) - the pilot signal[6]. With the corresponding "coloring" of $T_{\text{п}}$ and T_0 (for example, with the modulation of these two signals at different frequencies), the subsequent simultaneous separation of these two signals by the corres-

*Numbers in margin indicate foreign pagination.

ponding synchronous detectors is possible. In this case, at the synchronous detector output we shall have signals which are proportional to the useful signal and the pilot signal

$$V_n \sim G T_n \Delta f, \quad V_0 \sim G T_0 \Delta f, \tag{1}$$

where G is the direct radiometer amplification coefficient in terms of the high, intermediate, and low frequency; Δf - band of frequencies used at high frequency.

It is apparent that when V_n is divided by V_0 variations in G and Δf are excluded. The division operation entails several difficulties [7]. The problem is simplified if division is performed by a digital computer. According to the theorem of computations (Kotel'nikov theorem [8]), we may replace continuous signals by a sampling of discrete values, and the interval Δt between two calculated points along the time axis must be no more than τ, i.e,

$$\Delta t \leqslant \tau, \tag{2}$$

where τ is the integration time constant of the radiometer output.

For an adequate channel comparison rate, which in general is determined by the speed of operation of the computer and the ADT (analog-digital transformer), we may disregard the change in G during the sampling time.

The method of ratios was used in observations with a radiometer having a maser at a wavelength of 1.35 cm. Figure 1 shows a functional diagram of the radiometer having a computer [9]. To equalize the channels corresponding to the irradiators T_{a1} and T_{a2}, a noise generator was used (*ГШП* in the diagram). Noise was produced for both channel T_{a1} and T_{a2}. The noise production level was controlled by remote control attenuators *ФА1* or *ФА2* . Low temperature calibration of the radiometer was performed using a noise generator *ГШК* .

The power of the noise production generator *ГШП* , operating in the modulating mode, was used as the pilot signal in this radiometer.

Figure 2 shows the voltage diagram images at the output of the detector УПЧ without the pilot signal and with it (a and b, respectively). The diagram shows the intensity of the pilot signal corresponding to the channel balancing.

The pilot signal and the useful signal are amplified by one and the same receiving-amplifying channel. The voltage controlling the operation of the commutator of intensity МФ and the pilot signal modulation voltage are taken from the common generator ГОНо, but with a phase displacement of about 90°, which provides great isolation at the output of the signal and control channels. The polarization measurement channel (M"V" in the diagram) has a modulation frequency which differs from the first two channels.

Voltage from the outputs of all three channels is supplied to the commutator ПК, and further to АЦП. In our case, the signal and control channel commutation rate is 3 msec. The required integration time (numer of recordings) is given by means of a programming device.

During the observation process the noise production level must change (for example, during observations of the reference and unknown radio sources, observed at different zenith distances z). It is thus desirable to obtain the ratio of the temperature recorded by the antenna to the intensity of the calibrated ГШ ($T_{\text{гш}}$), and not to the ГШ intensity. When processing information on the computer, in order to obtain the ratio $T_a/T_{\text{гш}}$, it is necessary to determine the state of zeros of the radiometer analog output (УПТ), and the final value of balancing the channels T_{a1} and T_{a2} in terms of noise. Therefore, in our case before introducing the useful information into the computer (the recorded intensity from the radio source) by means of programming, we introduce the test information (state of zeros of УПТ, and we tie the temperature ГШП to the temperature ГШК, in order to obtain $T_a/T_{\text{гш}}$). /201

Let us examine the order for introducing the information by stages. For purposes of simplicity, we examine two channels (for a larger number of channels, the sequence of operations remains the same).

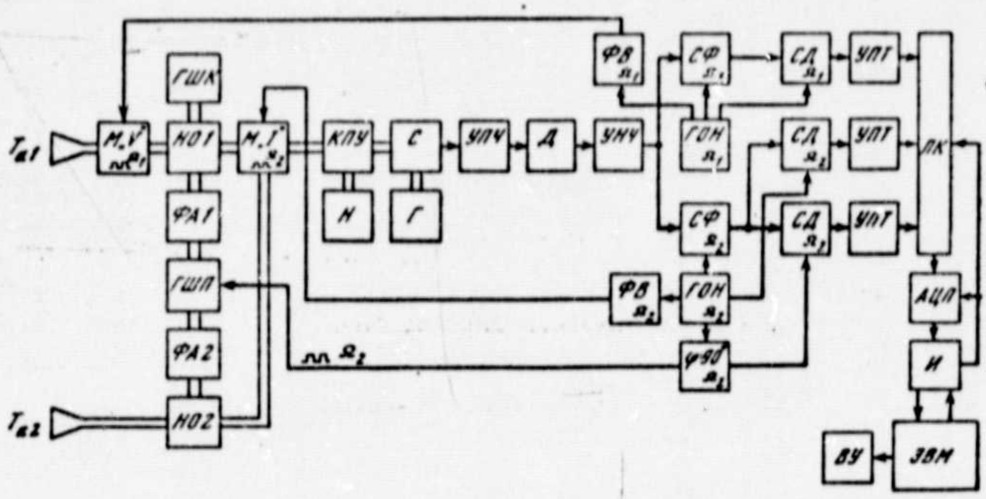

Figure 1. Radiometer Functional Diagram
гшк - calibration generator; но - directional couplers; кпу - maser; Н - pumping generator; С - mixer; г - heterodyne; д - square detector; фв - phase shifter; сд - synchronous detector; ву - output devices. The remaining notation is given in the text.

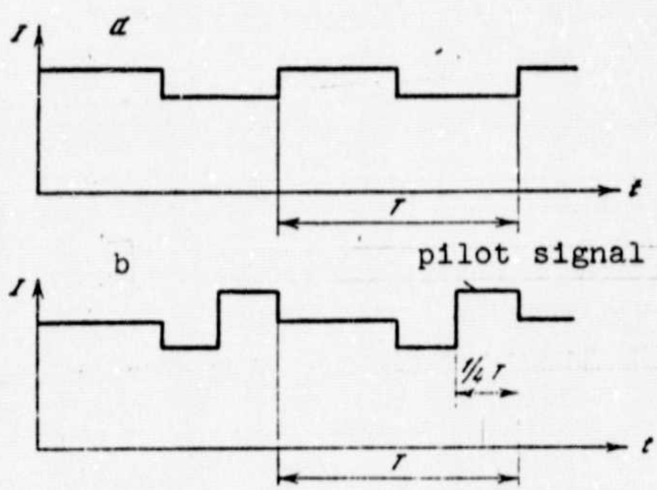

Figure 2. Diagrams of voltage at the square detector output
a - channels are not balanced; b - channels are balanced

Stage 1. The voltages $V_{i0}^{\kappa,c}$, corresponding to the state of zeros of the УПТ of the control and signal channels respectively, are introduced into the computer, and the mean arithmetic values of these voltages are calculated

$$\left(\sum_{i=1}^{n} V_{i0}^{\kappa,c}\right) \Big/ n = \bar{V}_{0}^{\kappa,c}. \tag{3}$$

Here, k and c are the indices designating the control and signal channels, respectively. i - number of the reading; n - given number of readings.

Stage 2. The working scales are turned on (on which the calibration and recording of the pilot signal will be carried out). The pilot signal is supplied to the control channel. The following is introduced in the computer

$$\Delta V_{i0}^{c} + V_{i0}^{c}, \quad V_{in}^{\kappa} + V_{i0}^{\kappa}. \tag{4}$$

Here ΔV_{i0}^{c} - is the voltage increase caused by an inaccuracy in the balancing of channels T_{a1} and T_{a2}; V_{in}^{κ} - voltage corresponding to /202 the pilot signal intensity (in our case, the noise production level).

In intervals between readings (4), the computer subtracts $\bar{V}_{0}^{\kappa,c}$ from (4) (subtraction of УПТ zeros)

$$\begin{aligned} \Delta V_{i0}^{c} + V_{i0}^{c} - \bar{V}_{0}^{c} &= \Delta V_{i0}^{c}, \\ V_{in}^{\kappa} + V_{i0}^{\kappa} - \bar{V}_{0}^{\kappa} &= V_{in}^{\kappa} \end{aligned} \tag{5}$$

and the ratio of the voltages in the signal and control channels is determined

$$\Delta V_{i0}^{c} / V_{in}^{\kappa}. \tag{6}$$

After taking the given numer of readings (6), the mean is calculated

$$\left(\sum_{i=1}^{n} \frac{\Delta V_{i0}^{c}}{V_{in}^{\kappa}}\right) \Big/ n = \overline{\left(\frac{\Delta V_{0}^{c}}{V_{n}^{\kappa}}\right)}. \tag{7}$$

Stage 3. The calibration signal $T_{\text{гш}}$ is turned on (signal channel). Thus the state of the control channel (up to the end of a given cyle of observations) is the same as before (pilot signal is turned on), and the following information is introduced

$$V^{c}_{iк} + \Delta V^{c}_{i0} + V^{c}_{i0};\quad V^{к}_{iп} + V^{к}_{i0}. \tag{8}$$

Here $V^{c}_{iк}$ is the voltage produced by the calibration signal. Similarly to operations (5)-(7) of the second stage, the computer subtracts $V_0^{к,c}$ and determines the ratio of the voltages corresponding to the signal and control channels, and also their average values. As a result we obtain

$$\overline{\left(\frac{V^{c}_{к} + \Delta V^{c}_{0}}{V^{к}_{п}}\right)}, \tag{9}$$

and the following difference is calculated

$$\overline{\left(\frac{V^{c}_{к} + \Delta V^{c}_{0}}{V^{к}_{п}}\right)} - \overline{\left(\frac{\Delta V^{c}_{0}}{V^{к}_{п}}\right)} = \overline{\left(\frac{V^{c}_{к}}{V^{к}_{п}}\right)}, \tag{10}$$

i.e., the control channel is calibrated. After this, *ГШК* is turned off and we may turn to recording the signal of the object being observed.

Stage 4. (Observations). The antenna is aimed at the radio source being studied. The following information is introduced into the computer

$$\begin{gathered} V^{c}_{i\,ист} + \Delta V^{c}_{i0} + V^{c}_{i0}, \\ V^{к}_{iп} + V^{к}_{i0}, \end{gathered} \tag{11}$$

where $V^{c}_{i\,ист}$ is the voltage proportional to the antenna temperature from the source (T_{a1} or T_{a2}). Similarly to operations (5), (7), (9), and (10) of the second and third stages, we calculate the average arithmetic value of the ratio of the intensities from the source and the pilot signal

$$\overline{(V^{c}_{ист}/V^{к}_{п})} \tag{12}$$

and we determine the average value of the ratio of the antenna temperature from the source to the temperature *ГШК*

$$\overline{\left(\frac{V^{c}_{ист}}{V^{к}_{п}}\right)} \Big/ \overline{\left(\frac{V^{c}_{к}}{V^{к}_{п}}\right)} = \overline{\left(\frac{V^{c}_{ист}}{V^{c}_{к}}\right)} \sim \frac{T_{a}}{T_{ГШ}}. \tag{13}$$

As may readily be seen, in the second, third, and fourth stages the computer performs similar operations, which makes it possible to formulate a sufficiently short and simple computational program.

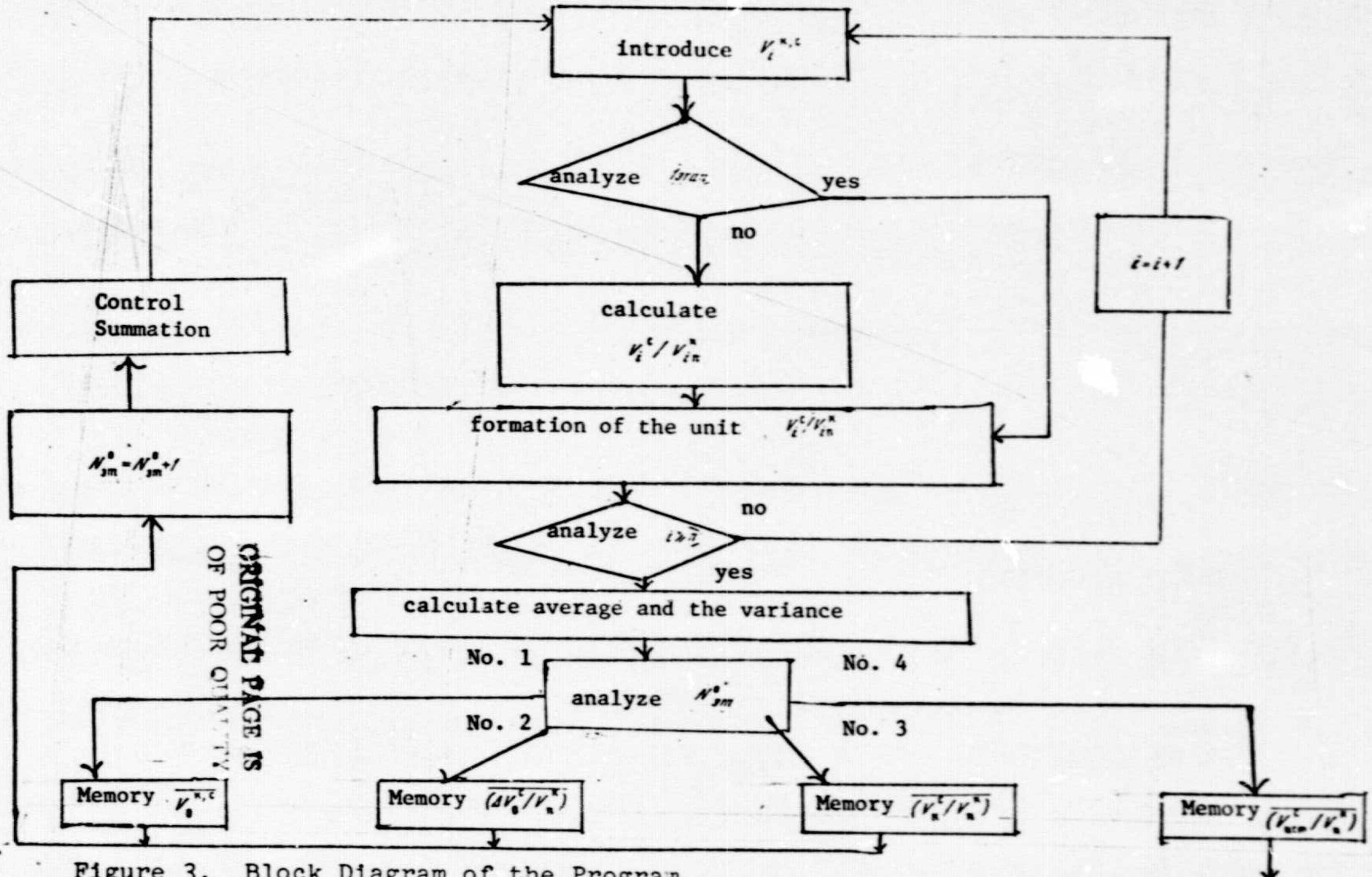

Figure 3. Block Diagram of the Program.
Notation in the figure is the same as in the text. $V_i^{c,\kappa}$ is information introduced into the computer and corresponding to definite stages and channels; $N_{\text{ЭТ}}^0$ - number of corresponding processing stage

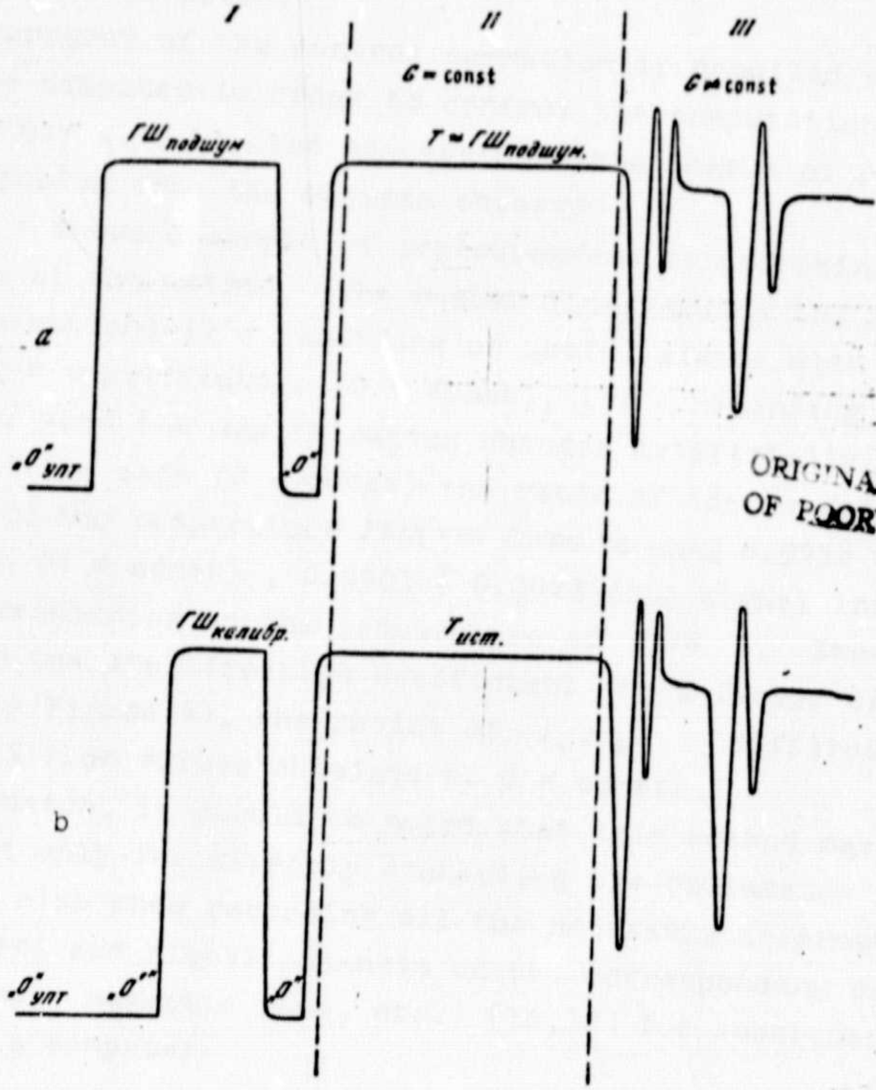

Figure 4. Example of recording signals over two channels
a- control; b - signal

After each average value is calculated, the mean square error is determined, and the final error is determined using the method of variance addition.

Figure 3 gives a block diagram of the program corresponding to thestages described above and illustrating the sequence of operations performed on the computer.

A sub-program of the control summation is compiled after each stage of the computer in order to control the computational accuracy. The program may also be used to determine the degree of polarization of radio emission from the objects observed.

Figure 4 shows a sample of registrograms illustrating the implementation of the method. The number I designates the introduction of test information; II - recording of useful signal with no change in the radiometer amplification (G = const); III - recording of the useful signal when the amplification changes artificially (G ≠ const).

In the first case (G = const) the ratio of the useful signal temperature to the temperature ГШК was found to equal 0.9958 ± 0.0012; in the second (G ≠ const) , 0.9901 ± 0.0023 (the signal intensity was selected corresponding to the temperature of ГШК). Even for large variations in the amplification coefficient (by a factor of 10, as may be seen in Figure 4), the ratios of $T_a/T_{\text{ГШ}}$ differed by no more than 0.7% from values obtained at G = const.

In conclusion, it should be noted that this method may be fully used not only for directly connecting the radiometer to the computer, but also when recording all the necessary information taken from the control and signal channels on the corresponding carriers (perforated tape, magnetic tape, etc.) [10,11] for subsequent processing on a computer.

REFERENCES

1. F.V. Bunkin, N.V. Karlov. ZhTF, 1955, 25,430, 733.
2. V.S. Ablyazov, B.N. Shvetsov. Voprosy radioelektroniki, 1961, series 1, No. 12.
3. N.A. Yesenkina, D.V. Korol'kov, Yu.N. Pariyskiy. Radioteleskopy i radiometry (Radiotelescopes and radiometers). Moscow, Nauka Press, 1973, 285 pages.
4. V.A. Yefanov, I.G. Moiseyev. Izvestiya Krymskoy astrofiz. obs., 1965, 34, 53.
5. Yu.F. Yurovskiy. Izvestiya Krymskoy astrofiz. obs., 1965, 34, 60.

6. A.E. Ohm, W.W. Shell. Bell System Techn. J., 1963, 42, No. 5
7. R. Zhilinskas. Izmeriteli otnosheniya i ikh primeneniye v radioizmeritel'noy tekhnike (Ratio meters and their use in radio measurement technology). Moscow, Sov. Radio, 1975.
8. V.A. Komel'hikov. In the collection: Problemy pomekhoustoychivosti radiosvyazi (Problems of radio communication noise stability). Moscow, Gosenergoizdat, 1947.
9. S.L. Domnin, V.A. Yefanov, Ye.S. Korsenskaya, V.A. Korsenskiy, I.G. Moiseyev, N.S. Nesterov, I.D. Strepka. Present volume, p 205.
10. V.A. Yefanov. Izvestiya Krymskoy astrofiz. obs., 1974, 51, 154.
11. M.G. Larionov, A.A. Kapustkin, I.G. Moiseyev, N.Ya. Nikolayev, P.N. Smezhka. Izvestiya Krymskoy astrofiz. obs., 1973, 47, 206.